SPECTRAL ANALYSIS OF ULXs IN PAIRS OF INTERACTING GALAXIES M51 AND NGC 4485/90 USING SWIFT-XRT

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ABSTRACT

In this study, we report the examinations of the spectra of ULXs in two nearby (< 10 Mpc) pairs of interacting galaxies M51 and NGC 4485/90 collected by Swift-XRT observations from 2005 to 2014 and 2008 to 2015 for each target, respectively. We consider 9 ULXs in M51 and 5 ULXs in NGC 4485/90. We obtain 116 ObsIDs of M51 and 37 ObsIDs of NGC 4485/90. For each pair oF interacting galaxy, there are about 10% data that do not meet our criteria for further Analysis.

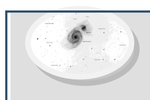
The count rate of individual observation ranges from 0.00003 to 0.05 counts/s in 0.3-10 keV band with typical error bar ~ 30%. Some ULXs in M51 exhibit a considerable fluctuation of intensity, up to three times, from 0.01 counts/s to 0.03 counts/s. ULXs in NGC 4485/90 show more stable light curves with no significant changes in intensity. For every source, we divide the data into two categories, e.g. hard-state (those with hardness ratio ≥ 1) and soft-state (those with hardness ratio < 1). Due to the short exposure time during the observations, we got low S/N data with wide error bar. Therefore, we combine spectrum from many observations with similar spectral characteristics for fitting purpose. We fit the co-added spectra with commonly used models: disk blackbody, power law and the combination of several models.

1 INTRODUCTION

Ultraluminous X-ray sources (ULXs) are bright, off-nuclear X-ray sources whose luminosity ranges between 10^{39} — 10^{41} erg/s. The nature of ULXs remains an open question since its discovery in 1970s until today. ULXs are found in all morphological types of galaxies (Swartz et al. 2004; 2011) although most of them are observed to reside spiral galaxies. Study of ULXs are commonly focused on bright ones and those located in nearby galaxies (in the order of several MPc). This yields bias due selection effect if that kind of study is going to be used to describe general properties of ULXs.

We aim to study ULXs as a population in a galaxy. Interacting galaxies are known to host a higher average number of ULXs (> 5). Therefore it is interesting to study ULXs as a population in interacting galaxies, as the first step for population study of ULXs. For this purpose, we choose M51 and NGC 4485/90 interacting galaxies as our main concern.

2 Swift-XRT Data



M51

116 OBSIDs ('05—'14) d = 8.4 MPc 9 ULXs

ID	RA (hhmmss.ss)	Dec. (ddmmss.ss)
ULX1	132939.45	+471243.70
ULX2	132943.30	+471134.70
ULX3	132950.67	+471155.10
ULX4	132953.31	+471042.30
ULX5	132953.72	+471435.90
ULX6	132958.38	+471547.40
ULX7	133001.02	+471344.00
ULX8	133007.56	+471105.90
ULX9	133006.03	+471542.40

NGC 4485/90

37 OBSIDs ('08—'15) d = 7.8 MPc 5 ULXs

ID	RA (hhmmss.ss)	Dec. (ddmmss.ss)
ULX1	123030.60	+414142.00
ULX2	123043.20	+413818.00
ULX3	123030.80	+413911.00
ULX4	123036.30	+413837.00
ULX5	123032.30	+413918.00

Number of ULXs and their position are taken from Liu & Mirabel (2005).

d_{M51} from Vinko et al. 2011, $d_{NGC\ 4485/90}$ from Tully 1988

3 DATA PROCESSING with HEASOFT v6.16

Individual Level 1 Swift-XRT data, typical exposure ~ 2000 seconds

Data reduction — XRTPIPELINE

Clean event files

Extraction

Region filtering:

1 background position far from source in each galaxy for all ULXs,

Energy filtering:

0.3—10 keV

XSELECT

Product 1 : Individual spectra, light curves, HR

STRATEGY

1. Create ARF file using XRTMKARF.
2. Group individual spectra using GRPPHA, group min 20, sys_err = 10, applying corresponding background, ARF, RMF (following www.swift.ac.uk/analysis/xrt/rmfarf.php grade 0—12)

Therefore

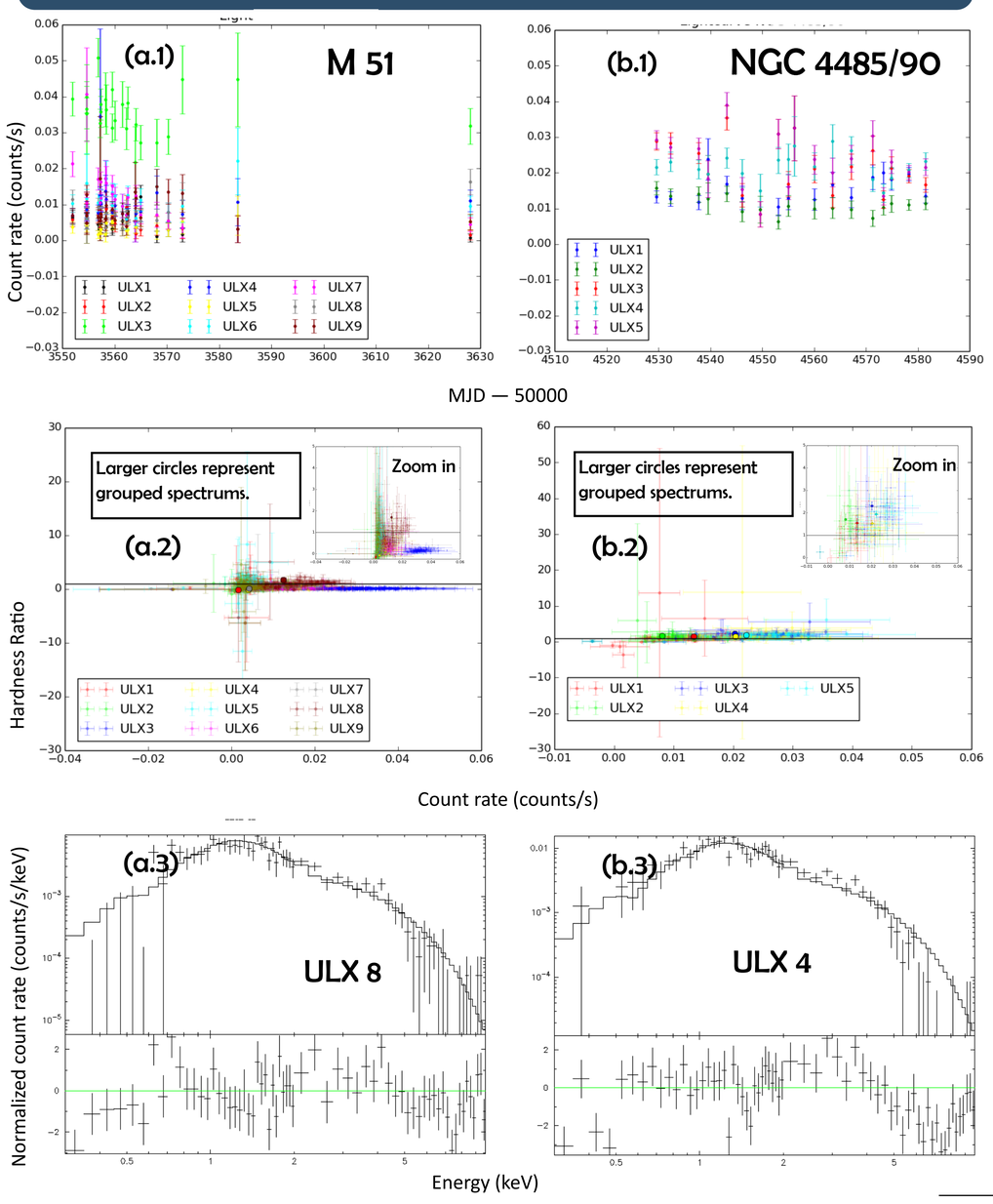
STILL POOR QUALITY

. Combine spectra with similar characteristic using ADDSPEC, based on HR and RMF files.
. HR defined to be = H/S
. S = count rate in low energy range (0.3—1.5 keV)
. H = count reate in high energy range (1.5—10 keV)
. Corresponding background are also added
. ARF files are added using ADDARF.
. Regroup co-added spectra with necessary adjustment.

Fitting

Chi-square statistical analysis from Xspec is used in fitting process. All data are treated equally.

4 RESULT and DISCUSSION



Figures a refer to M51, b to NGC 4485/90. The light curves (sample on Figures .1), show ULXs in M 51 have more fluctuations than those in NGC 4485/90. Figures .2 provides all hardness ratio from Product 1 which is used to justify spectral addition. Figures .3 give sample of spectral fitting in both galaxies using simple power law.

Spectral fitting are successfully carried out for 3 ULXs in M51 and 5 ULXs in NGC 4485/90. Fitting parameters are given in the bottom tables. ULXs in M51 show spectral transition and can be described by power law (PL) and multi color disks (MCD) while ULXs in NGC 4485/90 are more uniform. They can be explained by simple power law (PL). ULXs with HR greater than or equal to 1 belong to hard class, while the others belong to soft class.

Other ULXs in M51 do not give good fitting and need further special treatment. Some of them give negative value of count rate after being substracted by background. Reduced chi square value are high since the data quality are still poor even after spectral addition. This is a preliminary result.

Future plan:

. Use better statistical method for spectral analysis.
. Try other background locations.
. Add spectrums with different RMF

ID	n_H (10^{22} cm^{-2})	Pho_Index	kT_{in} (keV)	Chi square/dof	Class	Model
ULX 1	0.06 (fixed)	2.94 +/- 0.28		16.20/16	Soft	PL
ULX 4	0.06 (fixed)		0.19 +/- 0.01	35.55/25	Soft	MCD
ULX 8	0.46 +/- 0.09	2.12 +/- 0.02		57.24/53	Hard	PL

Fitting parameters of 4 ULXs in M 51

ID	n_H (10^{22} cm^{-2})	Pho_Index	Chi square/dof	Class	Model
ULX 1	0.59 +/- 0.14	2.38 +/- 0.24	63.6/53	Hard	PL
ULX 2	0.44 +/- 0.12	2.21 +/- 0.24	35.35/35	Hard	PL
ULX 3	1.03 +/- 0.16	2.28 +/- 0.18	46.4/32	Hard	PL
ULX 4	0.37 +/- 0.07	1.92 +/- 0.13	51.6/40	Hard	PL
ULX 5	0.69 +/- 0.16	1.89 +/- 0.19	23.68/16	Hard	PL

Fitting parameters of all ULXs in NGC 4485/90

Remarks

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